

The MOA 1.8-metre alt-az wide-field survey telescope and the MOA project

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ABSTRACT

A new 1.8-m wide-field alt-az survey telescope was installed at Mt John University Observatory in New Zealand in October 2004. The telescope will be dedicated to the MOA (Microlensing Observations in Astrophysics) project. The instrument is equipped with a large 10-chip mosaic CCD camera with 80 Mpixels covering about 2 square degrees of sky. It is mounted at the f/3 prime focus. The telescope will be used for finding and following microlensing events in the galactic bulge and elsewhere, with an emphasis on the analysis of microlensing light curves for the detection of extrasolar planets. The MOA project is a Japan-New Zealand collaboration, with the participation of Nagoya University and four universities in New Zealand.

Key words: optical telescopes – wide-field fast survey telescopes; gravitational microlensing; extrasolar planets

1 INTRODUCTION

The MOA (Microlensing Observations in Astrophysics) project was established in 1995 as a joint project between Nagoya University, Japan, and the universities of Auckland, Canterbury and Victoria and Carter Observatory in New Zealand. Massey University at Albany, NZ, is now also a member. About 20 scientists are involved in several institutions in Japan and NZ (but mainly Nagoya, Auckland, Canterbury, Victoria and Massey universities). All observations for MOA have so far been made with large CCD cameras mounted on the Boller and Chivens 61-cm f/6.25 Cassegrain telescope at Mt John University Observatory of the University of Canterbury. The coordinates are latitude $-43^{\circ} 59.2'S$, longitude $170^{\circ} 27.9'E$, altitude 1025 m.

Current MOA research includes CCD observations of crowded star fields in the galactic bulge and in the Magellanic Clouds to detect gravitational microlensing events. Difference imaging software is used as this is ideal for finding stars that have changed in brightness in crowded star fields. MOA issues microlensing alerts to the international community (see www.physics.auckland.ac.nz/moa/) and also makes follow-up observations of high magnification and other microlensing events of interest. Although the primary goal

of MOA is the detection and characterization of extrasolar planets in microlensing events, secondary goals are the analysis of finite source microlensing events, the detection of planets by photometric transits, the search for dark matter, the analysis of variable stars and the detection of optical afterglows from gamma-ray bursts.

In June 2002, one of us (Muraki) was successful in obtaining a grant for a new larger telescope for MOA observations at Mt John. The grant provides funds over 5 years (2003–2007) for the telescope, large CCD camera, dome and initial observations. The telescope was constructed by the Nishimura Company in Kyoto, Japan in 2003–2004. Design requirements were a large field of view $\sim 1.5^{\circ}$, a fast focal ratio (f/3 was chosen) and good imaging over approximately 380 nm to 1 μ m.

The optical design was undertaken by A. Rakich (IRL, Lower Hutt, N.Z.) and incorporates an f/2.75 primary mirror, giving a focal ratio of f/2.91 at the prime focus after passage through the four-lens aberration corrector. The scale at the focal plane is 38.7"/mm (0.57"/pixel). On the 10-chip CCD camera the detected field of view is $1.32^{\circ} \times 1.65^{\circ} = 2.18$ square degrees.

2 TELESCOPE INSTALLATION AND COMMISSIONING

The construction of the telescope was commenced in 2003. The contract for the primary mirror went to Littkarno in Moscow. The material is Astrosital low expansion ceramic. The mirror was figured and polished at the Lomo company in St Petersburg. The CCD camera was designed and constructed at the STE Laboratory of Nagoya University. It has a closed cycle cooling unit and 10 butted EEV $2k \times 4k$ thinned back-illuminated CCDs. The pixel size is $15 \mu m$ square and each chip is an EEV type CCD44-82. Four corrector lenses are required in the light path in front of the final image plane to correct for astigmatism and coma. All are from BK7 glass and have spherical surfaces. The lenses were fabricated at IRL in N.Z.

Three filters are available for the microlensing observations. They were made by Custom Scientific in Phoenix, AZ, and are 270 mm in diameter, 15 mm thick. They correspond to Bessell V, Bessell I and MOA broad-band red (90 per cent transmission from 632 to 860 nm). The filters are mounted between lenses #2 and #3 near the prime focus.

The Nishimura company completed the telescope by mid-2004 and after a trial assembly it was disassembled and shipped to New Zealand. A 9-m diameter dome was also built by Nishimura. At Mt John the building was commenced in June 2004. The dome was installed in September of that year and the telescope in October. The telescope had a formal opening ceremony on 1 December 2004, but the prime focus corrector lenses were not installed until early 2005.

First light was on 2005 April 14. Since then the telescope has been undergoing commissioning tests which have involved aligning the optical elements, and minor adjustments to the CCD camera to improve its performance. At the time of writing (mid-2005), routine operation of the telescope for the MOA project is imminent.

3 THE MOA PROJECT: RECENT RESULTS AND FUTURE GOALS

Some highlights of the MOA project in the last few years, based mainly on observations with the smaller 60-cm $f/6.25$ Cassegrain telescope at Mt John, are noted here. They include:

- (i) Detection of the first ever confirmed extrasolar planet by microlensing (with OGLE group, 2003) (MOA-2003-BLG-53) (Bond et al. 2004)
- (ii) Analysis of high magnification event MOA-2003-BLG-32 to show the absence of low-mass planets over a wide region of space around the lens star (Abe et al. 2004)
- (iii) Measurement of the microlensing optical depth towards the galactic bulge (Sumi et al. 2003)
- (iv) Analysis of limb darkening of the source star in the microlensing event MOA-2002-BLG-33 (Abe et al. 2003)
- (v) Analysis of stellar shape, also in MOA-2002-BLG-33 (Rattenbury et al. 2005)
- (vi) Contribution to the discovery of the second extrasolar planet discovered by microlensing, OGLE-2005-BLG-71 (Udalski et al. 2005)
- (vii) Detection of 12 transiting objects ranging in size from $1.7 - 3.2 R_J$ using MOA data obtained 2000–02; they

are possible new planets (hot Jupiters), periods 1 - 4 days (Abe et al. 2005)

It is noted that the MOA 0.6-m telescope contributed most of the data to the first confirmed planet by microlensing (Bond et al. 2004) as well as to a possible earlier event involving a lens with a low mass planet in 1998 (Bond et al. 2002). The MOA 1.8-m telescope has already made observations that are likely to contribute to new planetary events in the near future.

In the future the MOA project will continue a vigorous campaign on detecting and announcing new microlensing alerts. MOA will follow up these alerts so as to find new extrasolar planets, with the assistance of our world-wide collaborators, and hence characterize the properties of Jovian and terrestrial mass planets orbiting other stars.

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